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POLICY AND PROCEDURE DIRECTIVE

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TO: ALL MANUAL HOLDERS	PPD NO. 04-1
SUBJECT: END PRODUCT ASPHALTIC CONCRETE ACCEPTANCE TESTING – PROCEDURE FOR DETERMINATION OF STATISTICAL OUTLIERS	EFFECTIVE DATE: January 30, 2004

1. GENERAL

1.1 This procedure deals with the problem of outlying observations in sample test results and how to test the statistical significance of them. This procedure is adopted from ASTM E 178 *Dealing with Outlying Observations.* This procedure is intended to be used with end product type asphaltic concrete specifications such as 406, 416, and 417. Either ADOT or the Contractor may raise the question of whether an observation is an outlier.

1.2 An outlying observation, or "outlier," is one that appears to differ significantly from other sample test result values in the same population from which it was taken. Two general alternatives are of interest when considering outliers:

a) The outlying observation may be an extreme value of the population caused by the random variability inherent in the data. If this is the case, the observation should be retained and used in the same manner as the other observations.

b) The outlying observation may be the result of gross deviation from the prescribed sampling and/or testing procedures or an error in calculating or recording the numerical value. If this is the case, the observation should be discarded.

1.3 The procedure below provides the steps to take to make the decision whether,

a) The observation is not an outlier and should not be discarded, or

b) The observation is an outlier and should be discarded.

2. PROCEDURE

2.1 Determine whether a testing related physical reason exists for the outlying test value. If a physical reason exists, the outlying test value is excluded from pay factor calculations. Normally, only the individual test value is excluded; the test results for the entire sample are only excluded when the physical reason for the outlying test value applies to the entire sample.

2.1.1 Possible physical reasons for excluding a test value include:

a) *Damaging the sample prior to testing.*

b) *Gross deviation from prescribed test procedure.* If it is determined that a gross deviation from the prescribed test procedure has occurred, the resulting observation should be discarded, whether or not it agrees with the rest of the data.

c) *Test equipment malfunction.*

d) *Computational error was made.* If a computation error is found, it may be corrected and the corrected value used as the test result.

e) *The test result is outside the range of possible results.*

2.1.2 The following are examples of reasons that are **NOT** sufficient for excluding a test value:

a) *The sample was taken from a segregated area of the mat.*

b) *The acceptance test results do not agree with the quality control results.*

c) *The core had paint on it.*

d) *The test result is larger/smaller than all the rest.*

e) *The hot plant malfunctioned.* This is an assignable cause for the test result being different, because the material is different. It is not a reason for discarding a sample or a test result.

2.2 When a physical reason cannot be determined for an apparent outlying value the following calculation procedure should be used to determine whether the test result meets statistical criteria as an outlying value.

3. CALCULATION PROCEDURE FOR DETERMINATION OF STATISTICAL OUTLIERS

3.1 This procedure is based on a two-tailed t-test with a level of significance of 2%, adopted from ASTM E 178 *Dealing with Outlying Observations.* The use of a two-tailed test means that the outlier may be either on the high or the low side of the average. The 2% level of significance means that if it is decided that the value is an outlier, there is only a 2% chance that it is not.

3.1.1 Determine whether there is an assignable cause for the apparent outlier. An assignable cause means that a reason exists for the material being different, for example:

a) The sample was taken at the end of a truckload.

b) There is visible segregation at that location in the mat.

c) The paver wings were dumped at the sample location.

d) The plant was having problems.

e) The loader operator put the aggregate in the wrong bins.

3.1.1.1 If there is an assignable cause, the sample should not be excluded and the analysis should not proceed.

3.1.2 Identify the sample set to be used in the statistical analysis. The statistical procedure being used bases its criteria on the assumption that the samples are part of a normal population. This means that all samples used in the analysis must be part of the same population. Lots produced under different mix designs (or when there have been significant changes to the mix) are to be considered in different populations and should not be combined for the purpose of determination of statistical outliers. A target value change does not always indicate a significant change to the mix.

CASE 1: Compaction

For determination of statistical outliers in compaction lots, use all of the core results from the lot with the suspected outlier. Thus, n is normally 10 for the determination of compaction outliers.

CASE 2: Mix Properties

For determination of statistical outliers in mix properties, use all of the test results from the lot with the suspected outlier and the two previous lots. Thus, n is normally 12 for the determination of mix property outliers. If any of these lots has been refereed, the referee data should be used.

If there are not two previous lots with the same mix design (or it is the first or second lot in the project), following lots should be used. For example, if the lot containing the suspected outlier is the first lot of a new mix design, use the two following lots in the analysis. If the lot containing the suspected outlier is the second lot of a new mix design, use the previous lot and the following lot in the analysis. If there are not three consecutive lots with the same mix design, the analysis is conducted using only the samples in one or two lots (n will be less than 12).

3.1.3 Calculate the sample average ($\bar{x}$) and standard deviation (s) of ALL of the samples in the sample set using the equations below. The suspected outlier is **NOT** excluded from these calculations.

$$\bar{x} = \frac{\sum x}{n} \qquad (1)$$

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}} \qquad (2)$$

Where:
$\bar{x}$ = average of sample test values
x = sample test value
n = number of samples
s = standard deviation

NOTE: Round $\bar{x}$ to one decimal place more than the data used to calculate it and s to two more decimal places more than the data used to calculate it.

3.1.4 Determine the critical value for T from Table 1 using the total number of samples (n) in the sample set.

Table 1
Critical Values for T at 2% significance level (two-tailed test)

n	T
3	1.155
4	1.492
5	1.749
6	1.944
7	2.097
8	2.221
9	2.323
10	2.410
11	2.485
12	2.550

3.1.5 Determine the lower outlier limit (LO) and the upper outlier limit (UO) using the equations below.

$$LO = \bar{x} - (T \times s) \qquad (3)$$

$$UO = \bar{x} + (T \times s) \qquad (4)$$

Where:
LO = lower outlier limit
UO = upper outlier limit
$\bar{x}$ = average of sample test values
T = critical value from Table 1
s = standard deviation

NOTE: Round LO and UO to the same number of decimal places as the test values.

3.1.6 Provided there is no assignable cause for the occurrence of the test result in question, discard test data which falls outside of the lower and upper outlier limits calculated with equations 3 and 4. The entire sample is not discarded, only the outlying test result.

4. EXAMPLE CALCULATIONS

EXAMPLE 1: Suspected Compaction Outlier

The following 10 core densities were obtained. Is core number 4 an outlier for density? No physical reason or assignable cause could be identified for the low density.

Core	1	2	3	4	5	6	7	8	9	10
Density (pcf)	141.5	141.8	142.3	138.3	141.6	142.0	141.6	141.7	141.0	141.2

$$n = 10$$

$$\bar{x} = 141.30$$

$$s = 1.117$$

From Table 1, $T = 2.410$

$$LO = \bar{x} - (T \times s) = 141.30 - (2.410 \times 1.117) = 138.6$$

$$UO = \bar{x} + (T \times s) = 141.30 + (2.410 \times 1.117) = 144.0$$

Because the density for core number 4 is below the lower outlier limit (LO), core number 4 should be discarded and pay factor determinations should be made using the remaining 9 cores. Note that the calculated values for LO and UO are rounded to the same number of decimal places as the test data, in this case one decimal place.

EXAMPLE 2: Suspected air voids outlier.

The following test results were obtained for three consecutive lots on a project. Is Lot 3, Sample 1 an outlier for air voids? No physical reason or assignable cause could be identified for the high air voids.

Lot 1 Results:

SAMPLE NO.	Bulk Density (pcf)	VOIDS (%)	RICE (pcf)
1	151.8	4.2	158.5
2	152.1	5.8	161.4
3	152.1	4.0	158.5
4	153.2	4.7	160.8

Lot 2 Results:

SAMPLE NO.	Bulk Density (pcf)	VOIDS (%)	RICE (pcf)
1	152.4	4.8	160.0
2	152.7	4.3	159.6
3	152.6	4.3	159.5
4	152.7	3.5	158.3

Lot 3 Results:

SAMPLE NO.	Bulk Density (pcf)	VOIDS (%)	RICE (pcf)
1	149.5	7.3	161.3
2	151.7	5.0	159.7
3	151.9	4.5	159.1
4	151.5	4.9	159.3

$n = 12$

$\bar{x} = 4.78$

$s = 0.981$

From Table 1, $T = 2.550$

$$LO = \bar{x} - (T \times s) = 4.78 - (2.550 \times 0.981) = 2.3$$

$$UO = \bar{x} + (T \times s) = 4.78 + (2.550 \times 0.981) = 7.3$$

The air voids for Lot 3, Sample 1 are equal to the UO, thus this value is not an outlier and should be included in the pay factor determination. (The value in question must be outside the lower and upper outlier limits to be considered an outlier.) Note that the calculated values for LO and UO are rounded to the same number of decimal places as the test data, in this case one decimal place.

IMPORTANT NOTE: The fact that the bulk density for Sample 1 of Lot 3 is an outlier (see Example 3 below) does not make the air voids an outlier.

EXAMPLE 3: ***Suspected outlier in bulk density, when it is used to calculate the compaction target value.***

The data for this example is from a project where the compaction target is calculated as 98% of the bulk density. Using the data in Example 2 above, is the bulk density for Lot 3, sample 1 an outlier? No physical reason or assignable cause could be identified for the low bulk density.

$$n = 12$$

$$\bar{x} = 152.02$$

$$s = 0.934$$

From Table 1, $T = 2.550$

$$LO = \bar{x} - (T \times s) = 152.02 - (2.550 \times 0.934) = 149.6$$

$$UO = \bar{x} + (T \times s) = 152.02 + (2.550 \times 0.934) = 154.4$$

The bulk density for Lot 3, Sample 1 is below the lower outlier limit (LO), thus the bulk density for this sample should be discarded and the compaction target value for Lot 3 should be determined using the average of the remaining 3 bulk densities. Note that the calculated values for LO and UO are rounded to the same number of decimal places as the test data, in this case one decimal place.

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